UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Region 8
Albuquerque, New Mexico

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TERRACING OF CULTIVATED LANDS

Recommended Practices as Determined
By Evaluation Surveys in Consultation
With Interested Technical Sections.

Regional Bulletin No. 56
Evaluation Survey Series No. 1
April 24, 1939

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Through taking measurements of terraces constructed in this Region during the past four years, requesting the opinions of various members of the Service personnel and reviewing all available printed matter concerning terracing in other areas, this report has been compiled for use as a guide in carrying on terracing operations in the future.

Several types of terraces are in general use in other areas at this time, some being considered as merely variations of one general type, such as the broad base, while others are known by different names, such as diversion terraces, which correspond to narrow bases. To eliminate confusion in terminology and narrow these classifications, three general types have been selected to cover the field for the purpose of discussion. These are termed the impounding, open, and narrow base terraces. Definitions of each are as follows:

Impounding Terraces

In these semi-arid states the problem of soil and water conservation is of major importance and, although the problem in other localities may lie wholly in handling excess runoff, we need, in the majority of cases within this Region, to utilize all available waters in crop production. As a result of this condition the level broad based terrace having partially closed ends has been developed and is proving successful under the proper conditions.

It follows that to impound waters and still retain freeboard, the terrace height must be entirely independent of depth of borrow pit, and in all instances the crest or top of this terrace will be level. We then can define the height of impounding type terrace as being that distance from top of terrace ridge to natural ground level on the center line, and its width as being the distance between points where the fill meets natural ground on the upstream and downstream sides.

Figure I - Height "h" and width "w" shows this relationship for the impounding type.

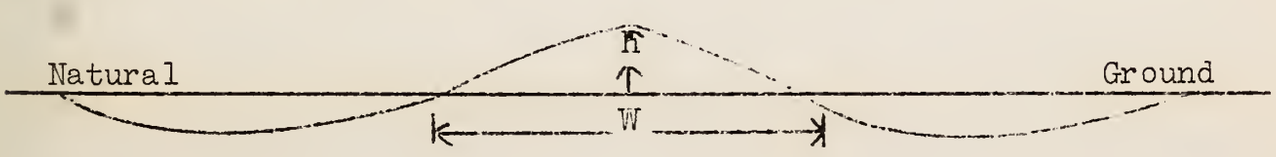

FIGURE I

Open Terraces

In locations where soils are relatively impermeable or where runoff problems are acute, the problem resolves into which is the best method to use in taking care of runoff regardless of water utilization, hence the need for terraces with open ends and, where necessary, their being graded.

If terrace ends are to be open, then it follows that the (uphill) borrow pit becomes a part of the delivery channel and the cross-section radically changes from that of the impounding type. The height then becomes the distance from bottom of borrow to top of ridge, and width is the distance between toes of slopes, regardless of fill or cut. In constructing this type of terrace, the borrow pit elevation is continued level or graded to a point of outlet, and the cross-sectional area of flow includes the borrow pit as well as the section of channel above the natural ground. Needless to say, such a structure will cost considerably less than the impounding type.

Figure II - Height "h" and width "w" shows this different cross-section for the open type.

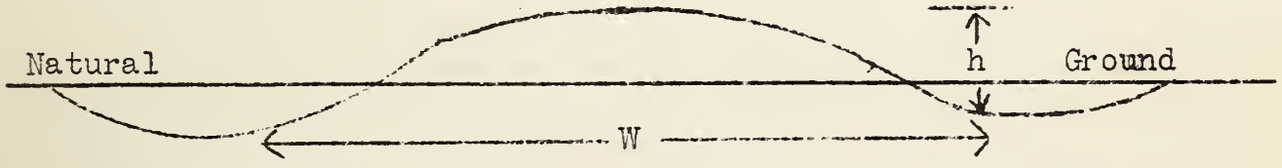

FIGURE II

Narrow Base Terraces

Within this category are included all terraces of such dimensions that they cannot be included as a part of normal farming operations or are used on range areas. There are, of course, several possible types that can be employed, depending upon whether it is desired to impound water or merely divert runoff. The height and width of this terrace will vary exactly as that variation between the impounding and open end terraces.

Suitable Types for Use Under Varying Conditions

To construct terraces of uniform shape and size, regardless of locality, soil type, topography, etc., appears to be entirely unreasonable to expect, and no amount of thought given to the subject when applied in the office can effect the need for application of common sense in field work. Therefore, it is suggested that certain types of terraces be recommended for use under a set of general conditions and that the selection of types be left to the field.

Opinions as expressed by various members of the field personnel, and related printed matter indicate that the use of broad base terraces should be discouraged on slopes greater than 8%. Some persons have suggested that 6% be made a maximum, but it appears logical that the broad base terrace, modified to have one or both ends open, may be economically and effectively used on the steeper slopes between 6% and 8%. By constructing only narrow bases on slopes greater than 8%, the cooperator is almost forced to plow on a contour and the danger of having these earth fills plowed down is minimized; also considerable earthwork will be saved.

The impounding terrace, save in those localities where soils and topography are unfavorable, will, through affording additional water for crops and retaining soil that would otherwise be lost, prove more successful in increasing crop production and reducing soil losses, confining their use, of course, to the accepted range of slopes. Since this type is considerably more expensive, the selection between impounding and open terraces resolves into a question of justification in the light of additional benefits accrued. It follows then that the impounding terrace, if considered economical, should be preferred in all localities where either might be safely constructed.

The open terrace then, if the increased expenditures necessitated by constructing impounding terraces are considered justified, will be used only in those localities where soils are unfavorable for water retention, slopes are equal to or below 8% and in certain special cases where, due to the length of terrace or quantity of water to be handled, graded terraces are considered necessary. The narrow base, of course, also can be graded where the higher slopes are to be treated.

Herewith is a summary of the recommendations made above:

1. To use only narrow base terraces on fields having slopes of greater than 8%.

2. If available funds permit, to use impounding terraces on fields having slopes of 6% or less, except in those cases where unfavorable conditions exist for this type.

3. To use open terraces in those instances where no water retention is desired or water delivery is of primary importance, this on slopes of 8% or less. When slopes rise above the maximum of 8%, the narrow base is to be used, either of level or graded construction.

Terrace Heights

As pointed out above, the height of a terrace above natural ground must vary, depending upon the type under consideration, yet there is little reason why the height of ridge above bottom of waterway cannot remain a uniform dimension when applied to the three types, since the waterway, whether it be entirely above ground or partially in excavation, should function in a constant manner. There will no doubt be a slight difference in friction losses between the two, yet this factor appears relatively unimportant, considering the variation found in specifications throughout the country and the future "unknowns", such as cropping systems, maintenance, etc.

By using the interpretation given above, we have but one height to consider, regardless of the type of terrace being discussed. Various publications concerning terrace dimensions and performances of terraces in the field indicate that the height now in more or less general use should be satisfactory; under ordinary conditions that of eighteen inches with an addition of 25% to this minimum for shrinkage plus the necessary addition in height at center line to compensate for that rise in elevation to the line of flow. This last addition will, of course, be necessary only when the terrace height is considered as being above natural ground. There will, of course, be certain conditions which can be taken care of by changing designs. In such cases, this set height should certainly be disregarded and changes made in both heights and vertical intervals.

Terrace Width

When analyzed, terrace widths become rather vague, since changes in types and slopes automatically change the width. It appears reasonable that rather than attempt a defined or standardized width for these terraces, we should establish minimum side slopes, thus leaving the widths merely a function of the other factors and to be changed at will with changes in design and type of terrace used.

There exists a divergence of opinion as to the proper slope for broad bases. Since recommendations have been made outlining slopes ranging from 4:1 to 8:1, however, a general average of these two, or 6:1, appears to have been the most popular. Hence, this side slope of approximately 6:1 is recommended as being both economical and practical, except in certain cases where large machinery is being used, in which case the 8:1 slope should prove more practicable.

It is realized that no broad base terrace will have straight slopes; that is not the intention, however any competent field man

can readily take a general average of the slopes and establish the completed curves to within a small percentage of error.

As outlined above, the narrow base terrace was not designed to function as a part of farming operations, rather as a dike to use in retaining or diverting runoff. For this reason, it appears logical to minimize the width of this type structure, leaving, of course, a factor of safety above normal stability. Again the actual base width need not be definitely fixed and the use of specifications slopes should suffice. Minimum slopes of 2:1 with a two-foot crown width should prove an ample cross-section if a structure of this size can be economically constructed by machinery now in use.

It is realized that the average grader can more easily handle earthwork when given a larger structure, and that these minimum specifications are considerably less than the probable result of machine-built terraces. To clarify the situation, a statement might be made to the effect that so long as these slopes are not steepened, the narrow base terrace should be constructed to the least economical width in keeping with the ability of the operator and machine, if, of course, the desired crown widths, slopes, and heights are obtained.

Terrace Lengths

It is obvious that some consideration must be given to the length of a terrace since the volume of water to be handled increases in proportion to the distance from point of greatest length from an outlet to the point of spill. The danger of inadequate freeboard becomes greater when level terraces are used, save in those of the impounding type where some storage is afforded below flow line.

To construct a terrace 1000 feet in length of like cross-section to that having a length of 4000 feet appears unreasonable, yet at times this has been done. It is recommended that at least six inches height be added with no change in vertical interval when lengths to point of spill must rise over 1500 feet, and that in as few cases as possible shall this distance be greater.

It appears preferable to use open terraces or narrow bases with open ends, preferably graded, if the greater lengths are necessarily used.

Insufficient data are available to offer other than those suggestions since the application of known hydraulic principles is, and has been seriously affected by such unknown factors as rate of silting, cropping systems, rainfall frequencies, etc., therefore it has been necessary to rely wholly upon the various

recommendations as found in publications and the results of our terracing program.

Terrace Grades

The open and narrow base types of terrace are, of course, subject to gradation, while the impounding type, as its name implies, will in all instances be of level construction.

In checking over grades as recommended for use in other states, it was found that a divergence of opinion existed as to all points save one, that these grades should be variable. This latter factor has met with almost unanimous approval.

The results of experimentation carried on by various Research Agencies definitely indicate considerably less soil losses from runoff when the least possible grades are used, and C. E. Ramser recommends that 4-inch fall per one hundred feet be considered as a maximum. His statement, that "no grade is insufficient, a 6-inch grade is too much, the 2-inch to 4-inch grade with a 4-inch maximum is preferable", appears sound when statistics supplied by experimental stations are consulted. It will be noted that Mr. Ramser's table given below does not agree in its entirety with the above statement, yet when considering that these grades are continued for comparatively short distances the conflict becomes less apparent.

Length	Fall per 100 Feet
0- 300	½"
300- 600	1"
600- 900	2"
900-1200	4"
1200-1500	6"

Assuming that the 4-inch grade was to be considered a maximum and the grade after passing 900 feet was to be kept constant at 4 inches, this table should fit in nicely with our work.

Terrace Construction

No attempts will be made at this time to suggest methods of constructing terraces, save to point out that the wide borrows having no defined "drop offs" are considered far preferable to narrow borrows with steep or vertical outside cuts, and preferably these outside slopes should be held to 6:1. The width of borrow pits will, of course, vary with different types of terracing, and slopes from natural ground into the borrow pits should be worked out in the field, remembering always that in the case of broad bases particularly, machinery must be moved over the entire area of distur-

bance and gentle slopes must be afforded.

There are many methods of borrowing earth for making the fill, the most popular of which appears to have been by taking material from both sides, yet a decided advantage is gained when all material is moved from the upstream side in that considerable more capacity for waterway is afforded, this when using the open type of terrace.

The handbook of Region 7, Soil Conservation Service, outlines a policy of operations for open terraces that appears sound. Their recommendations are as follows:

% Slope	% Borrow Upstream Side
2	50%
3	50%
4	60%
5	70%
6	80%
7	90%
8	100%

This change in construction methods can be employed in building impounding terraces also.

It may be well to mention at this time the necessary difference in constructing ends of terraces when the three distinct types are used, i. e., that when building the impounding type or narrow base with closed or partially closed ends, the grader blade is merely elevated at the end of borrow, while in constructing the open type or narrow base with open ends, the borrow must be turned down grade until its bottom elevation is reached on natural ground.

It is felt that the problem of handling concentrated waters at points of terrace outlets is of such importance and scope that an individual memorandum should be issued at a later date covering this subject, hence the omission of discussion herein.

At this time we do not have sufficient data covering the performances of various types of outlet structures to set forth definite recommendations.

Terrace Intervals

A check on intervals recommended for use in some fourteen localities other than this Region shows a variation in almost every case, yet heights as recommended by these same publications indicates very slight variations in comparison to these spacings. This condition in itself indicates a lack of sufficient experimentation or

possibly a lack of elapsed time since experimentation was started, and in addition emphasizes the influence of unknown factors, such as soils variations, cropping systems, silt deposition, etc.

A series of tables compiled by Mr. J. W. Jourdan of Region 8, based on the ability of various terrace heights to store varying runoffs, were found to coincide with the following formula for terrace spacings as adopted by Region 7.

$$N = \frac{6h^2}{M}$$

N = Vertical interval in feet.
h = Terrace height.
M = Runoff in inches.

This formula should prove adequate in taking care of spacings for different heights, save in cases where a maximum spacing must be adopted, hence it is recommended for future designs.

A check of designs recommended by other agencies and performance records of our own terraces indicate that the 2-inch runoff has been the most successfully used in terrace design, and should prove satisfactory in future operations.

As stated in the foregoing discussion, terrace heights may well be made variable when special conditions are encountered, and the formula given herein can well take care of any desired height. It appears dangerous, however, to drop the height below one foot, regardless of individual field opinions.

Due to conditions often prevailing at points of terrace outlets, adherence to a strict vertical interval is unreasonable, hence it is suggested that a variation from the recommended vertical interval of 0.3 foot be allowed when level terraces are being constructed, and 0.6 foot for those of the graded type.

The consensus appears to be that a distance between terraces of 300 feet should be established as a maximum regardless of height or slope. This then obviates the formula where spacing would be increased beyond that distance, and the maximum horizontal interval is the only consideration.

Terrace Maintenance

After construction is completed, the problem of silting and breaking down terraces through farming operations will remain to be reckoned with. It has been suggested that the "dead water" areas above impounding terraces be allowed to silt full, yet when this silting is completed we have lost our storage capacity and its beneficial effect, but will still have continued silting to contend with. As a result of these reasonings, it would appear reasonable to incorporate into each agreement, covering broad based terracing,

a statement to the effect that the cooperator is to back furrow to the center of the ridge from both sides, or through some similar procedure to continue moving silt deposited above the dike up onto the ridge, and returning to the ridge that material washed down as a result of rainfall.

Although the standard form of agreement theoretically covers all maintenance, nevertheless in this particular case the terrace maintenance problem should be worked out with the cooperator and incorporated into the plan of operations.

Locating Terraces

It is virtually impossible to outline just how terraces should be located on any particular field, yet the matter is of such importance that some attention should be given to the subject when making any report concerning terracing. There are in all instances, however, certain "musts" and "must nots" that cannot be disregarded.

Previous experience within this Region has made it rather painfully obvious that no field should be terraced that will receive waters other than those falling upon the unit being treated. This should be adhered to in every instance regardless of prevailing conditions. Some method must be devised whereby diversions and channels take excess waters from drainage areas above the field and handle such runoff in a manner independent of the terraces themselves.

We have had in the past various methods of locating terraces with relation to the true contour, in some instances attempting to follow the contour line to an extreme, while in others the opposite location or too great a divergence from contour was placed into effect. Again no set rule can be outlined, yet good judgment must be used in the field and a happy medium between those extremes established. It is suggested that both the Agronomist and farmer be consulted and the Engineer align terraces according to their joint general suggestions.

The most critical point in any terrace is normally its outlet, hence locations in any field should be made by means of selecting the most advantageous points for spilling, thence running into the field from those locations. It stands to reason that in carrying on a program of terrace construction, the protective measures, then upper terraces should be built first in the order named. This is especially necessary when work is in progress during our rainy season.

Too often in the past we have had cooperators whose isolated location with a group of non-cooperators made the proper handling of excess waters a problem almost insurmountable. Therefore, it is suggested that this factor of water disposal be thoroughly investi-

gated before a contract is initiated. Certainly if an attempt is made to treat this isolated tract and, due to inadequate facilities for handling excess water, severe damages occur to terraces and/or the field itself, we have failed as a demonstration agency.

Again it may be well to state that each field is an individual problem and, due to the many factors involved such as type and design of terraces to use, location of outlets, final water disposal, etc., extreme caution must be exercised throughout the job from original contact to signing of the agreement, if a successful terracing program is to be carried on in any particular area. This success will depend entirely upon the ability of field men to take the known facts at hand and apply them logically, though not similarly to individual fields.

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